An HF Mobile Antenna

by C R FRY, MSc, MIEE, CEng, G3NDI, ex-VE2ARO*

The author's interest in electronics dates back to his school days. He was licensed in 1957 while at Birmingham University, where he and a number of other students resurrected the University Radio Society.

Following a short period of UK employment after graduation, he worked at a Government research establishment in Quebec City. Since returning to the UK in 1969 he has been with EASAMS Ltd.

In recent years the pressures of car maintenance, lack of space, a major reconstruction of the family house etc, have left little time for amateur interests, or his other hobbies. He hopes that the extra house space will allow more room for amateur operation on vhf/uhf as well as hf bands.

SOME YEARS AGO, following my return from VE2, I bought a large, glass-fibre tube with the idea of using it for a high-performance mobile antenna. This tube was a two-piece blank with a short, internal jointing tube to enable the two sections to be separated easily. It was much later, however, after I bought a car with sufficient room to install a KW2000A and a home-constructed power supply, that this intention materialized. This article describes some of the design aspects of the antenna and installation problems.

Electrical design

There have been many articles in the literature describing electrically-short antennas using various techniques to circumvent the otherwise highly-reactive input impedance over most of the hf band. The main technique is

Photo 1. The whip antenna mounted with both centre and base loading coils. The base coil is shown completely bypassed. The two twisted copper strips are clearly seen on the bottom section

*7 Thornbury Close, Crowthorne, Berks RG11 6PE.

inductive loading, which is used to make the antenna appear longer electrically than its physical length. This loading may be distributed throughout the length of the antenna as a thin helix [1] or by a discrete coil. The earliest example of the latter appears in a brief mention in [2]. Other papers have described in detail the analysis of such loading [3, 4].

For my antenna, the possibility of using a thin helix wound along both sections of the tube was briefly considered, but the practical problems of tuning the whip for more than one band, and perhaps determining the number of turns needed, etc, would have required more time than was available. A discrete coil solution was therefore chosen.

The two parts of the glass-fibre tube were of equal length, which was convenient for the generally optimum positioning of the loading coil near the centre. I decided to minimize losses by using the thickest wire and largest coils that were reasonable. A large 10in by 2in "Airdux" coil in my possession could have been used at the centre, but it seemed more practical to use one of more modest size and see how the antenna behaved dynamically on its mount in the first instance. The coil was mounted on Perspex spacers just above the mounting box. As the overall length of the tube was 10ft, there was sufficient length for a λ/4 whip on the 28MHz band without loading. For this band the top section was directly linked to the bottom with a short length of wire. The complete antenna, mounted at the rear of my car, is shown in Photo 1.

A convenient way of making a quick-release mechanism with a good rf connection, was achieved by using blade terminals, which are available in various dc ratings from motor accessory shops; the crimping end was formed carefully round the antenna conductor, and then soldered to make a good joint. The centre coil had a connector at each end so that it could be completely bypassed, and the bottom, or base loading, coil had a single tapping point for 7MHz and three taps for 3·5MHz. The wiping action in joining these connectors helped to keep the contact surfaces clean.

The cast alloy box, mounted on a bracket made by the local

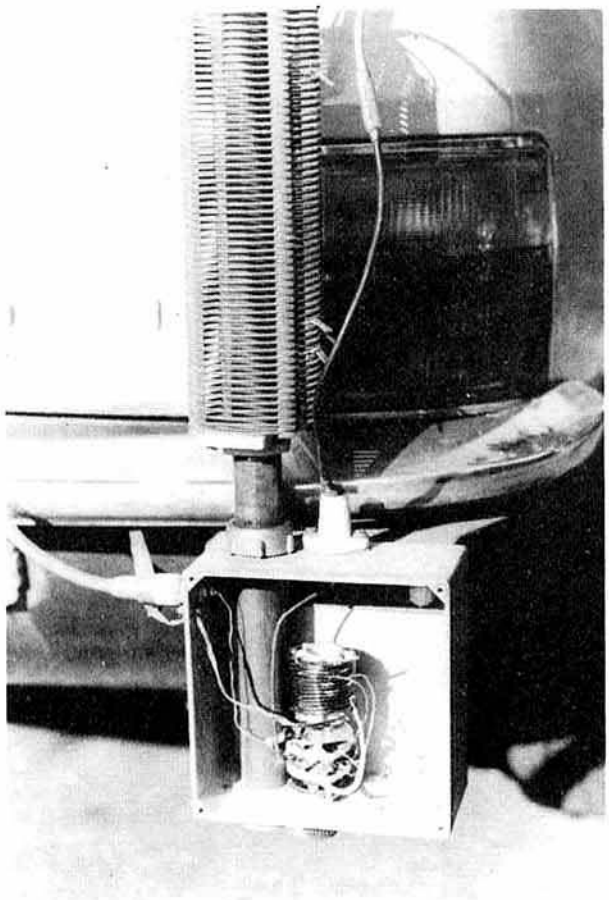

Photo 2. A close-up of the base mounting box with the lid removed, showing the matching coil and bandswitch. The use of 28mm plumbing fittings can be seen at the top and bottom of the box. A double-ended male coupling was carefully sawn in half. In the top portion a split compression ring is clamped by the large nut. It is sufficient to hand tighten the nut, and as a result the whip is quickly removed from the car

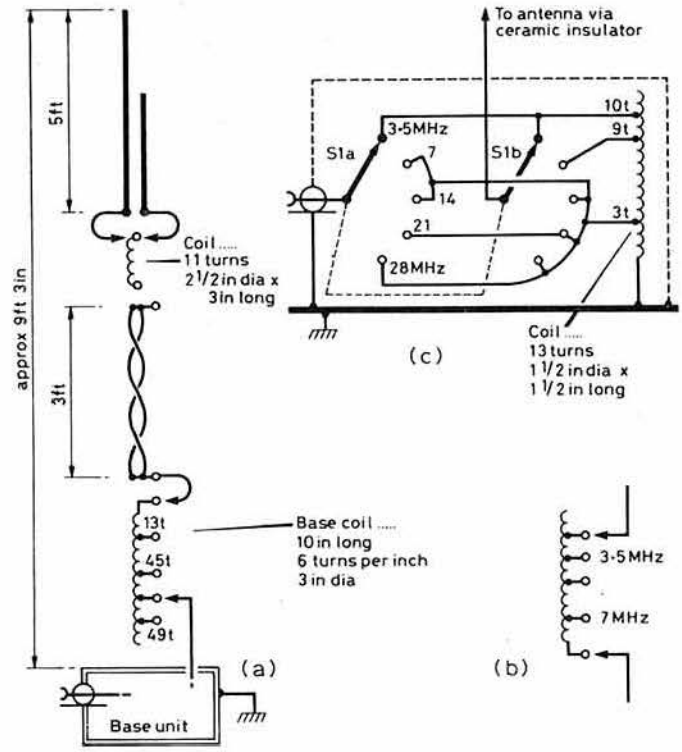

Fig 1. Details of the electrical construction of the whip. Connections to the base and centre coils are made with flexible, push-fit terminations. The base coil as originally tried is shown in (b). The switched matching coil inside the base unit is shown in (c). The overall height from the tip to the ground is approximately 11ft. The 3ft section is two lengths of 0·19in-wide flat, enamelled copper. On 28 and 21MHz the centre coil is bypassed. The shorter top section is cut to resonance on 28MHz. The longer section is used for all the other bands

blacksmith, supports the antenna and contains the small impedance matching coil and band-changing switch. A ceramic former and switch were used for this purpose and can be seen in Photo 2. The unoccupied space was intended for some form of automatic switching for band-changing with a suitable detector.

The coils and taps were cut-to-size with the aid of a homebuilt, dip oscillator and the station vswr bridge. The final result was the circuit shown in Fig 1. On each band the vswr achieved was very low, although on 3·5MHz at least the three taps mentioned earlier were required. A great deal of trouble was experienced with this bottom coil on 3·5/7MHz when attempting to load the transmitter, although the whip appeared resonant. This was eventually traced to the order of the connections on the coil, which had initially been as shown in Fig 1(b). Clearly some form of spurious coupling or resonance was the cause of the trouble as reversing the order effected a complete cure.

The centre coil was adjusted to provide resonance on 14MHz in conjunction with the three turns of the matching coil. The coil was bypassed on 21MHz, but used the same tap for matching with the longer of the two parallel wires on the top section. On 7 and 3·5MHz the centre loading coil was included in circuit. This had the effect of increasing the current flowing in the bottom section and effectively increased the radiation resistance. This resistance was in any case low for these bands with such a short antenna, and even an increase of 0·1Ω was desirable.

Mechanical construction

Unfortunately the body of the car did not allow a simple mounting arrangement to a solid chassis member. Furthermore, when mounted the antenna tip was some 11ft above the ground, so that a considerable wind leverage was exerted at high speed, and the vibration could also be a source of metal fatigue.

Steel angle and square tube for the mount were obtained from the local blacksmith. This was cut to size, notched where necessary, and then bent to fit the mounting position as shown in Fig 2. The assembly was taken to the blacksmith and temporarily held in position against the car while tack welds were made at appropriate points to hold the joints at the correct angles. The assembly was then removed for the proper fillet welds to be completed.

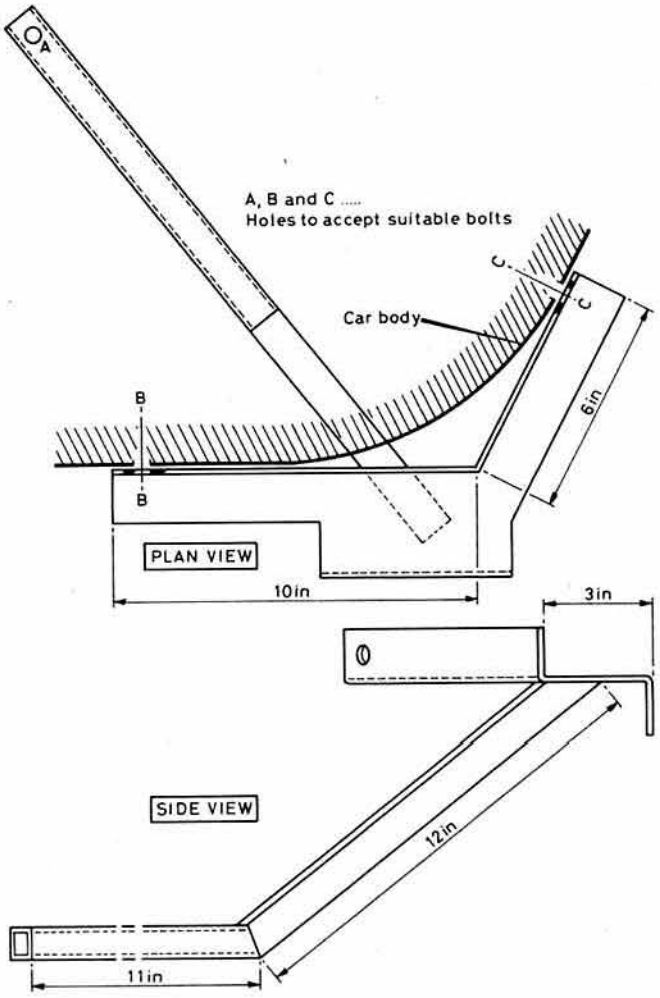

Fig 2. This shows the support bracket for the antenna. Bolt A is one of a number round the petrol tank circumference. Bolts B and C are those used to hold the bumper in place. The material used is mild steel angle of side 1·5in and 1in square section hollow bar. The finished bracket should be well cleaned and coated with a ferrous metal primer and top coat

The alloy box was fixed by two bolts in the position shown, using a steel plate under the heads to ensure the distribution of stresses over as large an area as possible. A steel box would have been a better choice if one had been available. A thin aluminium sheet was bent to form the lid, and to ensure a watertight seal a thin strip of inner tube rubber was glued to the mating surface. Four 4BA screws in the corners held the lid in place and ensured electrical continuity for the lid as a screen.

Although this mount was perfectly adequate when stationary, it was quite clear that provision was needed to stop any whipping and vibration when the car was moving; this would have rapidly caused failure of the box or other parts of the mount. An air louvre existed on the rear quarter of the car, and this was used to hold a thin nylon cord looped round the bottom section just below the centre loading coil. This cord was kept under slight tension and was found perfectly satisfactory in stopping any significant motion when the car was travelling at full speed.

Installation of the KW2000A

This transceiver is somewhat large compared to the latest solidstate units, but happily is still going strong and still with the original valves. It was positioned on the gear control hump on the car floor, and the power cables were passed through a grommet in the engine bulkhead. The power supply comprised two solidstate, power dc/dc converters in one box, based on the kit available a few years ago from G3LGK. The original transistors for the transmitter supply were changed to TIP35s.

Interference was expected during operation in the car, and this was borne out the first time the car was started. However, care had been taken to carefully screen various sections of the power supply and to use adequate hf decoupling. There appeared to be little power supply interference. The worst problem was found to be ignition noise and electric motor noise. The motor noise was quickly eliminated by placing 0·01μF disc ceramic capacitor directly across the brushes where possible. None of the normal techniques [5] had any appreciable effect on ignition noise, which gave a level of about S8 on the KW2000A S-meter. The electronic ignition was also changed back to the original contact breaker and coil without any noticeable effect.

Eventually it was decided that there was no option but to try screening the ignition. All the ht cable and sparking plug caps had already been changed in the first place. Clearly, before attempting what could be a lengthy task it was felt desirable to try and prove that the noise could be reduced. A roll of 0·5in-wide aluminium tape was used to wrap all the ht leads, and the ends were temporarily fixed to the nearest earth points. This had an immediate impact on the noise level, and kitchen cupboards were raided for some sheet aluminium foil, which was used for further screening round the distributor cap and the terminal end of the ht coil. While the effect was not as dramatic as before, the noise was now about S1/S2 and of little consequence compared with other noises, particularly from other cars' ignition systems.

The aluminium foil was removed and a more permanent installation carried out using braid on all the ht leads. A tin can was cut and soldered to form long, narrow tubes which slipped over each sparking plug. They were arranged to be a tight fit over the plug hexagon flats in order to ensure proper earthing. The ends of the braid were terminated in pigtails and small blade terminals. These pushed into corresponding sockets soldered to the plug screening cans.

A large, open-ended screening can was fixed to the ht coil, and the open end overlapped the end of the ht lead braid to which it was connected. Lucas make screening cans for some of their distributors, and one of these cans was purchased from the local agent. It is believed fully screened systems [6] are available, but these are normally only fitted to military vehicles because of the much higher cost involved. The use of the braiding and cans resulted in a simple and effective cure.

The alternator appeared to cause no interference. To complete the interference suppression, the bonnet was earthed to the body with braid straps, and the power supply was directly connected by braid to the engine

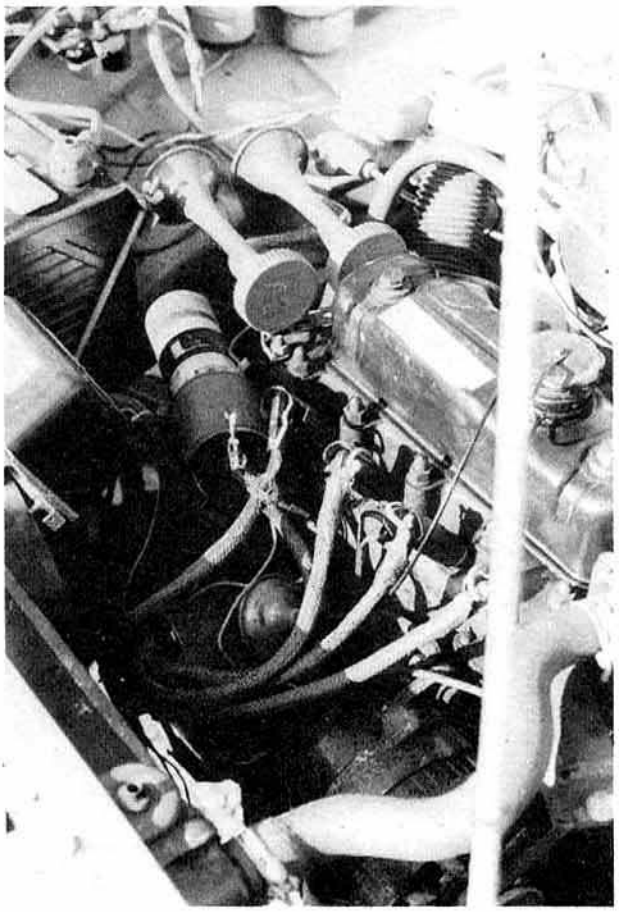

Photo 3. This shows the screening in place on the ht leads. The cans round the plugs, the ht coil and the distributor (lower centre) may be seen

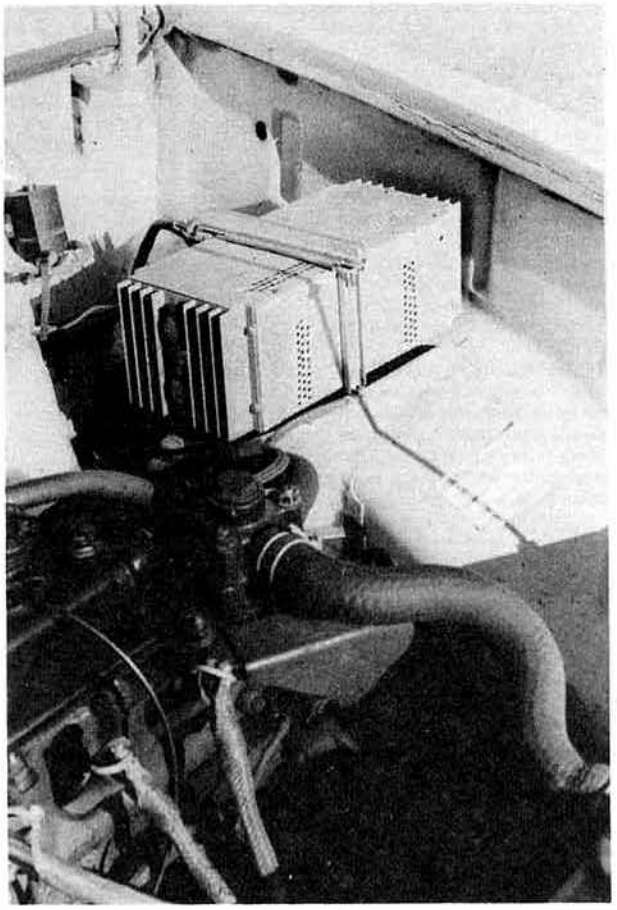

Photo 4. Another view showing a little more clearly the connections between the braid and the cans screening the plugs. The mounting arrangements for the power supply are also clearly illustrated

block. This seemed to have no effect but was done as a precautionary measure. The input cables to the power supply from the battery were left unscreened. The results of these efforts are shown in Photos 3 and 4.

Conclusions

The mechanical strength of the whip and its mount have been found quite satisfactory in all conditions, including motorway driving. Very little vibration is noticed owing to the stiffness of the glass-fibre.

The electrical performance has been outstanding on all bands and, in general, when a station has been called a contact has resulted. Reports have been received from the continental USA, Canada, Australia and New Zealand. Some of the more exotic European areas worked have been OH0, IH9 and HB0. On one occasion when calling VK3, the mobile signal was stronger than that of a nearby fixed station.

Slight problems have been experienced with the braid screen on one plug, where an intermittent arc formed between the braid and the entry of the cable into the plug. This was stopped by removing the earth pigtail and pushing the braid away from the plug.

References

[1] "Wide frequency range tuned helical antennas and circuits", A G Kandoian and W Sichak. *IRE Nat Conv Rec* Pt2, 1953 p42.

[2] "A solenoid whip aerial", W R Wilson. *Electronics* January 1941 p56.

[3] "Monopole with inductive loading", C W Harrison *IEEE Trans AP-11* July 1963, p394.

[4] "Efficiency and matching trade-offs for inductively-loaded short antennas", R C Hansen. *IEEE Trans COM-23,* April 1975, p430.

[5] "Suppression of vehicle interference for mobile radio operation", D W Morris, *Rad Com* May 1976, p337.

[6] *Radio Interference Suppression,* leaflets, Lucas Publication 2015, Sept 1960, and Bosch Handbook A2/1.

[7] "Short antennas for mobile operation", J S Belrose *The Mobile Manual for Radio Amateurs,* ARRL, 2nd edn, p125.

APPENDIX

Electrical parameters

The following calculations provide some estimates of various electrical parameters of the antenna and its performance. The calculations are only approximate, but for practical purposes are adequate. They are based on the procedures given by Belrose [7].

The inductance of an air cored coil is given by

$$L = n^2 \left[\frac{a^2}{9a + 10l}\right] \mu H$$

where n = number of turns
where a, l = coil radius and length
Using this expression, the following values are obtained

centre coil.....4·6μH
base coil.....55μH
matching coil (10 turns).....3·1μH

Radiation resistance

For a short antenna the maximum current amplitude exists at the feedpoint, and to a close approximation decays linearly to the tip. It is normal to refer the radiation resistance, R_r, to a maximum current point such as this. The resistance is given by

$$R_r = 0{\cdot}01215\ A^2\Omega$$

where A = the current distribution expressed as an area in degree-amp.

For a linear current distribution,

$$A = \frac{G}{2} \text{ for a current of 1A}$$

where G = antenna electrical height in degrees

For heights greater than about 0·2λ or 72°, this simple equation becomes progressively inaccurate. However, approximate values for R_r can be calculated as shown in the table below where the height h = 111in (see Fig 3).

Frequency (MHz)	Electrical height h		R_r (Ω)
3·7	0·034	12·2°	0·45
7·05	0·064	23°	1·6
14·15	0·13	46·8°	6·65
21·2	0·19	68·4°	14·2
29·0	0·26	95·4°	27·6

The value for R_r in the table is not correct when the centre coil is inserted, as the current distribution is altered towards a more constant distribution over the bottom section. Belrose [7] gives in his paper the additional equations for this case.

Losses

Using the nomographs in Beatty & Sowerby (*Radio Data Charts,* Iliffe, 1958) an estimate of the copper loss in the coils can be made, bearing in mind that the wire diameter used here does not necessarily meet the requirement to minimize the loss. The estimates are shown for just two frequencies.

	14MHz	3·5MHz
Centre coil	0·9Ω	0·4Ω
Base coil	—	1·4Ω
Matching coil	0·1Ω	0·2Ω

The earth loss resistance R_g is variable, but estimates may be in the range of 10–70Ω, for example.

Bandwidth

The operating bandwidth for this antenna provides no restriction on 7MHz and below. Some simple measurements in the author's drive (layer of asphalt/hardcore over dry sandy soil) gave a bandwidth, B = 220kHz at 3·725MHz, and including the centre coil the figures were 170kHz and 3·655MHz.

Using the normal equations

$$B = \frac{f_o}{Q} = \frac{f_o \times \text{total resistance}}{\text{coil impedance}} = \frac{f_o R}{2\pi f_o L}$$

then for the bottom tuning and matching coils

$$0{\cdot}22 \times 10^6 = \frac{R_g + 0{\cdot}45 + 1{\cdot}4 + 0{\cdot}2}{2\pi\,(55 \times 10^{-6} + 3{\cdot}1 \times 10^{-6})}$$

from which

$$R_g = 80{\cdot}3 - 2{\cdot}05 = 78{\cdot}3\Omega$$

Radiation efficiency

The power producing the received signal is that 'lost' via the radiation resistance. Assuming the above calculated value then on 3·5MHz without the centre coil the radiated power as a proportion of the input power is

$$= \frac{0{\cdot}45}{0{\cdot}45 + 1{\cdot}4 + 0{\cdot}2 + 78{\cdot}3} P_{in}\ W$$
$$= 0{\cdot}006\ P_{in}\ W$$

For 14MHz the ratio is better and becomes approximately

$$\frac{6{\cdot}65}{6{\cdot}65 + 0{\cdot}9 + 0{\cdot}1 + 78{\cdot}3} = 0{\cdot}08\ P_{in}$$